water movement by leaving the hoop station during the period of stimulus presentation, after which it received a fish reward.

As soon as the seal was blindfolded, it brought its whiskers into the most forward position. Although the whiskers of seals can be easily moved by muscular action, as has been described for manatees¹², our test animal did not actively move the protracted whiskers during a trial.

The harbour seal responded to extremely weak hydrodynamic stimuli. However, it never responded when wearing a muzzle of wire mesh, which let the water movement through but impeded whisker movements. The shapes of the threshold curves (Fig. 1b) — plotted as particle displacement (μm), velocity ($\mu\text{m s}^{-1}$) or acceleration (mm s^{-2}) against frequency (Hz) of the stimulus — are similar to those of behavioural and physiological threshold curves for other aquatic animals (see ref. 3 and references therein). The nearly constant acceleration threshold values in the range 10–50 Hz indicate that at lower frequencies the seal responded to the acceleration component of the hydrodynamic stimulus. At higher frequencies, water displacement seems to be the relevant stimulus parameter. A similar change in operation mode is achieved by the fish lateral line³.

With regard to absolute thresholds, the sensitivity of the seal's whiskers to hydrodynamic stimuli compares well with that described for hydrodynamic receptor systems of, for example, the decapod crustacean *Cherax destructor* or the marine teleost *Xiphister atropurpureus*, whereas the lateral line system of some species of fish may be more sensitive by up to one or two orders of magnitude (see ref. 3 and references therein). The seal could detect water velocity at speeds as low as $245 \mu\text{m s}^{-1}$, which in turn is several orders of magnitude below the water-particle velocities measured in the wake of a swimming fish of about 22 cm in body length¹³.

Our results show that the whiskers of harbour seals form a hydrodynamic receptor system with a spectral sensitivity that is well tuned to the frequency range of fish-generated water movements¹³.

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Alanine enantiomers in the Murchison meteorite

Engel and Macko¹ have reported that alanine indigenous to the Murchison meteorite has an L-enantiomer excess of about 33%. Furthermore, they reported very similar $\delta^{15}\text{N}$ nitrogen values for L-alanine and D-alanine; these values are quite high in comparison with those of terrestrial amino acids. On this basis, they argued that contamination of the meteorite by terrestrial L-alanine can be ruled out because, if it contributed to the L-enantiomer excess, the lower ^{15}N content of terrestrial L-alanine would significantly lower the $\delta^{15}\text{N}$ value that they observed for L-alanine.

In agreement with earlier analyses², we find the alanine from the interior of Murchison to be racemic and believe that incomplete chromatographic resolution of L-alanine and other meteoritic amino acids may have affected both the enantiomer ratio and the $\delta^{15}\text{N}$ determinations of Engel and Macko.

The Murchison meteorite contains a complex suite of amino acids. Whereas terrestrial samples are dominated by the 20 protein amino acids, over 70 amino acids have been positively identified in this meteorite, many of which appear to be uniquely extraterrestrial. Others are present that have not been positively identified. This complexity challenges methods of amino-acid analysis. For example, in our study of enantiomeric ratios of meteoritic amino acids³ we found that we needed a fractionation

Figure 1 Total ion chromatogram (Chirasil-L-Val, 50 m x 0.25 mm, Alltech) of amino acids (*N*-trifluoroacetyl isopropyl esters) from a desalted Murchison water extract. The dotted line is a single ion (*m/z* 180) trace. Amino acids were identified from mass spectra. 1, D-alanine; 2, 2-amino-2-ethyl butanoic acid; 3, L-alanine; 4, methyl proline isomer or unsaturated acyclic C6 amino acid; 5, D,L-2-methyl norvaline; 6, D,L-methyl alanine; 7, unsaturated C4 amino acid; 8, sarcosine.

step before gas-chromatographic analysis in order to avoid resolution problems.

We find that several meteoritic amino acids are racemic, including alanine. An L-alanine excess was seen only in an extract of a sample that included exterior fragments. Figure 1 shows the chromatographic resolution of alanine from this extract, in the same chromatographic phase (Chirasil-L-valine) as that used by Engel and Macko¹. There are five amino acids that elute over a period of about a minute, from just before L-alanine to sarcosine. Although only one of these amino acids overlaps L-alanine in our chromatogram, in the separation shown in ref. 1 the chromatogram seems to be compressed and baseline separation is not quite achieved between L-alanine and sarcosine. Thus it seems probable that more than one of these five amino acids eluted or overlapped with L-alanine, contributing to the appearance of an L-alanine excess. It is unlikely that these amino acids were absent in Engel and Macko's sample as different Murchison stones are qualitatively similar with respect to amino-acid content⁴.

We do not know the $\delta^{15}\text{N}$ values of the amino acids that we suspect may be interfering but, if their $\delta^{15}\text{N}$ values were close to that of indigenous L-alanine, their presence could go undetected isotopically. On the other hand, if their $\delta^{15}\text{N}$ values were greater than that of L-alanine, their presence could mask the presence of terrestrial L-alanine. Given Murchison amino-acid values of up to +184‰, it is clear that their chromatographic overlap, even if they were present in relatively small amounts, would increase the ^{15}N content of the L-alanine peak and compensate, wholly or partially, for the lower ^{15}N content of terrestrial L-alanine that might have been present.

In conclusion, Engel and Macko's argument that their chromatographic peak for L-alanine is composed almost entirely of meteoritic L-alanine depends on the peak containing only L-alanine. Their argument for a large excess of the L-enantiomer in the alanine indigenous to their Murchison sample would be greatly strengthened if they were to provide evidence that L-alanine and the closely eluting amino acids that we have identified were completely resolved in their gas chromatography/isotope-ratio mass spectrometry analyses. Such analyses of appropriate amino-acid standards might also help to establish whether or not incomplete resolution affected their result.

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